EXTERNAL INHIBITION OF THE CONDITIONED EYELID REFLEX

BY

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Gregory A. Kimble, Supervisor

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in the Graduate School of
Arts and Sciences
of
Duke University

1962

ABSTRACT

(Psychology-General)

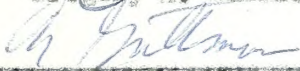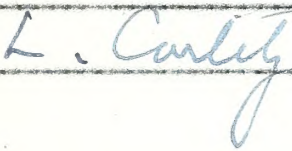EXTERNAL INHIBITION OF THE CONDITIONED EYELID REFLEX

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EXTERNAL INHIBITION OF THE CONDITIONED EYELID REFLEX

Henry Sutton Pennypacker, Jr.

The phenomenon of external inhibition has to a large extent been overlooked in American research on classical conditioning with human subjects. Several studies have shown that the presentation of a novel or extra stimulus prior to or instead of the conditioned stimulus will interfere with the production of conditioned responses, but none have attempted to verify the Pavlovian assertion that presenting an extra stimulus during the interval of delay will similarly inhibit conditioning. The present study is an attempt not only to verify this conjecture, but also to examine the effects of prior training and novelty of the extra stimulus on the amount of inhibition so produced. Finally, an attempt is made to confirm the Pavlovian notion that an extra stimulus which acts as an inhibitor during acquisition will act as a disinhibitor if presented during extinction.

Sixty subjects were administered 65 eyelid conditioning trials in which a red light appeared and was followed in 1.5 sec. by a puff of air to the right eye. These subjects were divided into three groups according to whether they received one, two, or three additional trials in which the onset of the tone preceded the delivery of the airpuff by .50 sec. The group which received only one such trial received it after 60 training trials; the group which received two received the first after 30 training trials and the second after an additional 30; the third group received their first tone trial after 15 training trials, their second after another 15, and

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their third after still another 3?. All groups were treated alike in extinction which consisted of three nonreinforced presentations of the CS followed by five nonreinforced presentations of the CS together with the tone in the same temporal relation as before.

The results strongly confirmed the expectation that the tone presented during the interval of delay would inhibit the production of conditioned responses in its presence. While the data as analyzed on the basis of groups showed no clear effect of prior training on the amount of inhibition produced by the tone, individual analysis revealed that subjects who exceeded the median number of total conditioned responses were more likely to respond in the presence of the tone.

Suggestive evidence for a disinhibition effect was found in the extinction data, but the absence of proper controls makes its acceptance somewhat tenuous.

Viewed in aggregate, the results tend to confirm the existence of external inhibition as a phenomenon amenable to laboratory investigation and are encouraging of efforts to further define its relationship to the other variables of classical conditioning.

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INTRODUCTION

One of the most basic phenomena studied by Pavlov in his pioneering
and definitive researches on conditioned reflexes is that of indirect or
external inhibition: the process by which perception of a new or unusual
stimulus disrupts or suppresses ongoing reflex activity. In almost all
cases, this disruption is thought to be occasioned by the evocation of a
competing investigatory reflex by the novel stimulus. In order to serve
as an external inhibitor, therefore, it seems very probable that a stimulus
must have the capacity of evoking an extraneous or orienting reflex.

Pavlov went on to specify in some detail the variety of effects
produced by the presentation of an external inhibitor and discussed the
conditions under which such effects were found to occur. He found, for
example, that the extent of inhibition of a well-established conditioned
reflex varied directly with the intensity of the external inhibitor. He
further showed that if the intensity of the external inhibitor was held
constant, then the degree to which a conditioned reflex was inhibited varied
inversely with the strength of the reflex as inferred from the number of

times its elicitation had been reinforced.

Undoubtedly of greater theoretical significance was Pavlov's discovery that the presentation of an external inhibitor did not always lead to inhibition of an existing conditioned reflex, but that in some cases the reflex was strengthened. He found this to be the case when the reflex in question was being subjected to some other form of inhibition at the time the external inhibitor was presented. Thus, for example, in the case of a well established reflex, presenting a novel stimulus early in the interval of delay often elicited the reflex which ordinarily should not have occurred until a point in time more nearly coincident with the unconditioned stimulus. Pavlov suggested that such an elicitation of the conditioned reflex was due to inhibition by the external inhibitor of internal inhibition of delay, the term used to describe the withholding of a conditioned response until reinforcement is imminent. Such inhibition of inhibition Pavlov called disinhibition. He went on to show that this too depends for its effect upon the intensity of the external inhibitor and the amount of inhibition present to be disinhibited which in turn depends again upon such things as the number of previous reinforcements.

These relationships are clearly exemplified in the following experiment conducted in Pavlov's laboratory. A conditioned salivary reflex had been established in a dog using tactual stimulation of the skin as a CS and acid as a UCS. After a considerable number of reinforcements the CR displayed the typical pattern of failing to occur until toward the end of the CS-UCS interval. In Pavlovian terms, this meant that early in the interval the response was held in check by inhibition of delay. Presenting mild odor of camphor together with the CS had no effect on the course of the CR; it was initially inhibited, then evoked. Presenting thermal stimulation at

50° C, again in conjunction with the CS, interrupted the primary inhibitory phase of the reflex and the animal salivated throughout the presentation of the two stimuli. Both the inhibitory phase and the later excitatory phase were disrupted when a whistle was blown during the presentation of the CS; the animal salivated early in the interval but the flow decreased as the UCS approached. Finally, when a loud whistle was blown, no conditioned response at all was made during the interval of delay.

Other types of internal inhibition can similarly be disinhibited by the presentation of an external inhibitor. Moreover, it follows that the same external inhibitor can on one occasion in an experiment inhibit a conditioned reflex though it facilitates the occurrence of the reflex on another occasion. Thus, Pavlov writes, "We have seen that the very same extra stimuli, which, when they evoke strong extraneous reflexes, produce external inhibition of the positive conditioned reflexes, produce, when their effect is weak from the start or weakened by repetition, disinhibition of the conditioned reflexes which were made to undergo extinction." (Pavlov, 1927, p. 67.)

The foregoing statement has, to the author's knowledge, been verified only once in the American conditioning literature. M. A. Wenger, in 1936, conditioned the GSR of human subjects to a red light, using a shock to the sole of the right foot as reinforcement. Twice during acquisition, he presented tactual vibration to the subject's left hand; he then recorded the amplitude of the GSR made to the next presentation of the light CS and found in each case that it was smaller than the response made to a nonreinforced CS presented immediately prior to the inhibitor. After extinguishing the response to its level prior to reinforcement, he again administered the tactual vibration and observed an increment in the GSR made to the immedi-

ately succeeding presentation of the CS. Wagner had divided his subjects
into two groups which differed according to the intensity of the tactual
vibration presented and found, as Pavlov would have predicted, an increase
in both the inhibitory and disinhibitory effects associated with the more
intense external inhibitor.

Effects like those of external inhibition can be found elsewhere in
the American conditioning literature. Hufort and Kimble (1956) compared
eyelid conditioning with and without a ready signal, the latter being a
buzzer of 1.6 sec. duration terminating 1, 3, or 4 sec. prior to the onset
of the CS. They found acquisition impaired in the presence of the ready
signal. McAllister and McAllister (1960) were able to replicate these find-
ings using the word "ready" instead of a buzzer and Chapman (1962) has ex-
tended both sets of results by showing that the degree of impairment of
conditioning varies inversely with the proximity of the ready signal to the
onset of the CS. A reasonable interpretation of these findings would sug-
gest simply that the orienting reflex, or traces of it, made to the ready
signal is, at the onset of the CS, activating parts of the subject's nervous
system necessary to conditioning; as this activation is given time to die
away, the resulting interference is diminished. In addition, Hufort and
Kimble present evidence which would suggest that the orienting reflex to the
ready signal diminishes in intensity, and hence in inhibitory capacity, with
repeated elicitations; the greatest differences in performance among their
groups occur early in training.

It will be noticed that both the Wagner experiment and those just
discussed differ from the Pavlovian experiments cited earlier in one impor-
tant theoretical detail: Pavlov applied his external inhibitors during the
presentation of the CS and therefore, according to him, at a time when na-

citatory or inhibitory states under the control of the CS were in effect.
The other investigators mentioned applied external inhibitors at times when
the CS was not present, though it is possible, particularly in the case of
the Berger experiment, to assert that lingering excitatory and inhibitory
effects, developed in the presence of the CS, were affected by the extra
stimuli.

A few American investigators have actually presented external inhibi-
tors during the operation of the CS (Hoemick, 1937; Spence and Runquist,
1958), but these investigations have invariably been concerned with the na-
ture of the response made to the external inhibitor, usually a very weak
stimulus used as a probe, rather than with the effect of the extra stimulus
upon the primary reflex.

With respect to disinhibition, Kimble (1961) has recently reported
observing such a phenomenon under conditions where some form of internal in-
hibition associated with the CS may have been assumed to be operating. In
this instance, however, the primary inhibition was observed as a diminution
of the unconditioned reflex; presenting an external inhibitor during the
interval of delay served in some cases to restore the amplitude of the un-
conditioned reflex. Since most investigators of the phenomenon of CS-con-
trolled inhibition of the unconditioned reflex feel that it is a result of
inhibition of delay (Shpalov, 1960; Kimble and Ost, 1961; Pennypacker and
Kimmel, 1961), Kimble's data may well represent the first American demon-
stration of disinhibition of inhibition of delay, at least where human sub-
jects are involved.

Finally, in a preliminary study in this laboratory, it was found
that a novel visual stimulus, presented instead of the usual visual CS after
15, 30, and 40 reinforcements, inhibited the conditioned eyeblink and that

the degree of inhibition varied inversely with the number of prior reinforcements. In contrast to Wenger's findings, however, was the suggestion that the presentation of the novel stimulus during acquisition was followed by a period of heightened excitation, a phenomenon labeled _induction_ by Pavlov. Unfortunately, all subjects in this experiment were administered the three trials involving the novel stimulus hence no controls were available against which to assess the presence and amount of such an inductive effect.

The present study was designed in an effort to correct this failing as well as to verify the inhibiting properties of a novel stimulus presented with, rather than instead of, the conditioned stimulus. Since the primary interest was in an inhibitory rather than a disinhibitory effect, it was decided that the external inhibitor should be presented during the second, usually excitatory, phase of the interval of delay rather than throughout the interval as Pavlov had done. This procedure was also adopted with the expectation that as a result of inhibiting the excitatory phase in this manner, inhibition of the CR might also be observed. Finally, to substantiate Pavlov's and Wenger's assertation that the same extra stimulus which serves as an inhibitor during acquisition will, in the presence of inhibition acquired as a result of experimental extinction, act as a disinhibitor, a series of post-extinction trials was administered with the extra stimulus added as it had been during acquisition.

METHOD

Subjects. The subjects were Duke University undergraduate students who participated voluntarily in order to fulfill a part of the laboratory requirement of an introductory psychology course in which they were enrolled. None had had previous experience in an eyelid conditioning situation.

Usable data were collected from 60 of the 77 subjects who participated. Nine of the remaining subjects were discarded as voluntary responders, 6 failed to produce at least 5 conditioned responses during the acquisition period, and an exceedingly high resting blink rate made the records of the remaining two unreadable.

The subjects were assigned serially in order of their appearance at the laboratory to one of three groups, differing only with respect to the number of acquisition trials administered with the external inhibitor present. The assignment of subjects to groups was partially restricted in order that each group of 20 subjects would finally be composed of 14 males and 6 females, approximately the ratio of the sexes in the parent population.

Apparatus. The subject was comfortably seated alone in a well-

lighted, sound-deadened cubicle whose internal dimensions were 6' x 3' x 7'. Immediately in front of the subject was a table-like shelf upon which he could rest his hands and forearms. Communication between the subject and the experimenter was available, when needed, through an intercommunication system.

Throughout the procedure, the subject wore a headpiece to which was attached the air delivery tube and a microtorque potentiometer. The arm of the latter was connected by means of a light cotton thread to a false aluminum eyelash which was taped to the subject's right eyelid; movements of the eyelid were thus mechanically transformed into movements of the potentiometer arm. These movements were relayed to a Grass Model 5 R driver amplifier through a 22½v. balanced connecting circuit designed and supplied by the Grass Instrument Company. The output of the driver amplifier was ink-recorded on one channel of a Grass Model 5 polygraph at a paper speed of 30 mm. per sec. Two event-marking pens were employed; one recorded the onset of the conditioned stimulus and the cessation of the unconditioned stimulus while the other marked the onset and cessation only of the unconditioned stimulus. The chart drive was started manually approximately 3 sec. before the onset of the conditioned stimulus and allowed to run until approximately 3 sec. after the delivery of the unconditioned stimulus.

The unconditioned stimulus, a puff of air, was delivered through a 3/64 inch aperature to the temporal corner of the subject's right eye from a distance of about one-half inch. The intensity of the air puff was maintained at the equivalent of 125 mm. of mercury as measured by a gauge and was controlled by a system of valves leading from a tank of dry compressed air. The duration of the air puff was .10 sec. and was controlled by the action of a solenoid valve.

The conditioned stimulus was a circular red light, 1½ inches in diameter, produced by a Grason-Stadler Model E 4580 multiple stimulus projector and mounted equidistant from either side at a height of 7½ inches in the cubicle wall facing the subject. The extra stimulus, or external inhibitor, was a 1000 cps tone delivered at an intensity of approximately 70 decibels (re: .0002 dynes/cm.²) by an RCA Beat Frequency Oscillator Model 154 through a 3½ inch speaker mounted in the wall of the cubicle to the subject's left.

All stimulus durations and interstimulus intervals were controlled by Grason-Stadler electronic interval timers. Trials were presented in a repeating sequence of 24-, 15-, 20-, 28-, 12-, 23-, and 17-sec. by means of a Gerbrands tape programmer whose action after the appropriate interval automatically initiated the sequence of events defining a trial.

Procedure. When the subject arrived at the laboratory, he was led into the cubicle and seated in a cushioned, reclining office-type chair with a padded headrest. He was told to lean back as far as he could in the chair and use the foot rest provided for his feet. The experimenter then began reading aloud the instructions (see Appendix A), pausing at the appropriate point to apply the headpiece and false eyelash and adjust the air delivery tube. The intent of the instructions was twofold: to acquaint the subject with the general procedure without revealing to him its purpose, and second, to inhibit the production of voluntary responses by introducing a set to "respond naturally." After eliciting and answering any questions, the experimenter left the cubicle and closed the door.

All subjects first received two trials with the conditioned stimulus alone followed by three trials with the unconditioned stimulus alone. This was done to familiarize the subject with the stimuli he was to encounter

and to provide a measure of responsivity to these stimuli prior to condi-
tioning. Paired conditioning trials were then presented with the onset of
the conditioned stimulus (CS) preceding the onset of the unconditioned stim-
ulus (UCS) by 1.0 sec.; the duration of the CS was 1.0 sec. so that its ter-
mination was coincident with the onset of the UCS. In trials involving the
tone as an extra stimulus, the onset of the CS preceded that of the tone by
.5 sec., both stimuli terminating together. All such trials were reinforced
during acquisition to prevent the development of discrimination and to per-
mit observation of the effects, if any, of the external inhibitor upon the
UCR.

Depending upon the experimental condition to which he was assigned,
the subject received 15, 30, or 60 such trials before receiving his first
trial with the external inhibitor present. Group I received 60 CS-UCS
trials, 1 trial with the external inhibitor, and five more CS-UCS trials.
Group II received 30 CS-UCS trials, an external inhibitor trial, 30 more
CS-UCS trials, then another external inhibitor trial followed by five CS-
UCS trials. Group III subjects received their first external inhibitor
trial after 15 CS-UCS trials, their second after the 30th CS-UCS trial,
and a third after the 60th CS-UCS trial, again followed by five final CS-
UCS trials. Thus, provision was made to compare subjects' performance fol-
lowing presentation of the external inhibitor after 15 and/or 30 reinforce-
ments with the performance of subjects who had not yet experienced the ex-
ternal inhibitor.

All subjects were treated alike in extinction. Three extinction
trials involving only the CS were administered, followed by five non-rein-
forced trials in which the tone was added to the CS as it had been in ac-
quisition. This procedure was carried out with 57 subjects, 19 from each

group. The first subject run in each condition was administered 16 straight extinction trials; subsequent addition of the tone produced no change in what was typical extinction behavior. This suggested that fewer non-reinforced presentations of the CS would be necessary to prevent the development of so much extinctive inhibition that no effects of the external inhibitor could be observed.

RESULTS

All data were derived from measurements and judgments made from the
ink-written records. The records were evaluated with the aid of a trans-
parent template; decisions concerning questionable voluntary responses were
made with the assistance of another experimenter who was experienced in
reading these records.

Definition of the dependent variable. A conditioned response was
defined as any deflection from a stable baseline in the direction of closure
that 1) was greater than or equal to 1 mm., 2) occurred at least 400 msec.
after the onset of the CS, and 3) did not return to the baseline prior to
the onset of the UCS. The first two of these specifications are, with minor
variations, in rather widespread use. The third, however, requires special
justification.

It is well known that the presentation of virtually any sufficiently-
bold novel stimulus will evoke an orienting reflex on the part of a human
subject and that one component of this reflex is an eyeblink. Since, as
Grant and Norris (1947) and others have shown, the latency of such a reflex

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blink may be as much as 115 msec., it was entirely possible in the present study for reflex (or alpha) blinks to the onset of the tone to be mistaken for conditioned responses on those trials in which the tone was intended to serve as an external inhibitor. By requiring that a conditioned response blend with the unconditioned response, the likelihood of inadvertently including alpha responses on these trials was greatly reduced since the duration of an alpha reflex is not apt to be more than 115 msec. As a check on the efficacy of this procedure, the data were tabulated with and without using the blending criterion. On the reinforced trials that included the tone, the blending criterion eliminated 39.4% of the responses that would otherwise have been classified as CRs; it eliminated only 16.4% of such responses on the other acquisition trials. It is assumed that this difference reflects the presence of alpha reflexes to the onset of the tone which were appropriately omitted from the analysis. In order to insure statistical comparability, however, the blending criterion was applied to all reinforced responses, thus making any statistical demonstration of external inhibition due to the presence of the tone somewhat more difficult than it would have been had the blending criterion only been applied to those responses made in the presence of the tone. The blending criterion was not used in the case of responses observed during extinction.

With the definition of the dependent variable established, it is proper to proceed to a consideration of the results of the experiment. For each group, Figure 1 shows the mean percentage of conditioned responses in acquisition (including the first extinction trial) plotted as a function of blocks of three trials. Performance in extinction is similarly plotted trial by trial for the three trials during which only the CS was presented. The open symbols in Figure 1 represent performance of the various groups on the

Figure 1. Mean percentage of conditioned responses for the three groups presented by blocks of three trials in acquisition and trial by trial in extinction.

MEAN PERCENTAGE CONDITIONED RESPONSES

BLOCKS OF THREE REINFORCED TRIALS

EXT. TRIALS

Group I
Group II
Group III
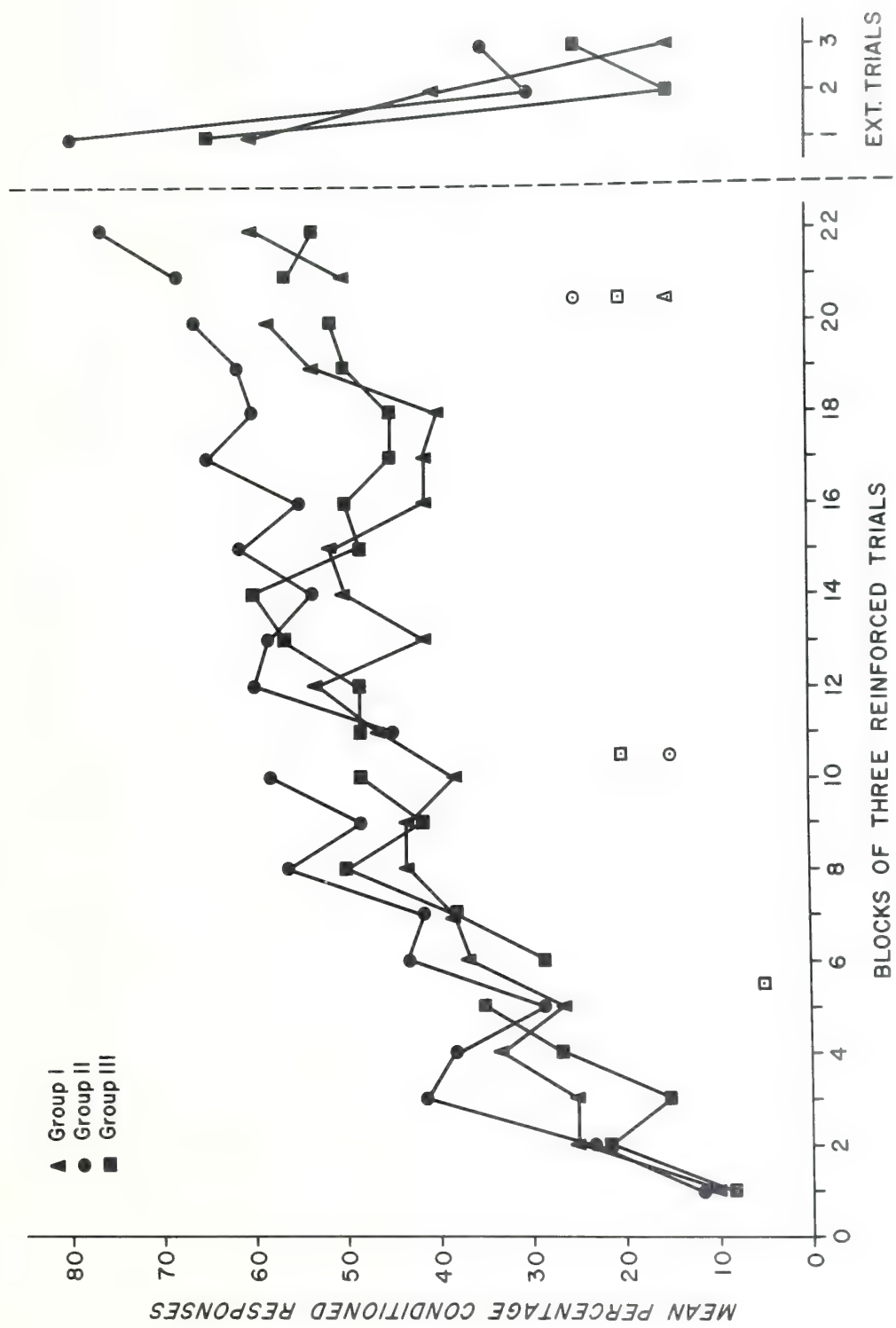
trials which included the external inhibitor. Inspection of the figure clearly indicates that a large decrement in performance resulted from presentation of the external inhibitor, but that the amount of decrement is not greatly affected either by the number of prior reinforcements or by the number of prior presentations of the external inhibitor itself. Statistical tests of all possible differences among these points confirm the latter impression.

The decrement which occurred in the presence of the external inhibitor was evaluated for each group separately by means of the Cochran Q test (Siegel, 1956); this technique simultaneously compared each subject's performance on the external inhibitor trial with his performance on each of the three immediately preceding trials. Similar analyses were performed on the pooled data of Groups II and III following 30 CS—UCS trials and on the data of all three groups following 60 CS—UCS trials. The results of these analyses, presented in Table 1, demonstrate that the decrement in performance due to the presentation of the external inhibitor is statistically reliable in every case.

Although analysis of the groups' performance on the external inhibitor trials reveals no differences which can be reliably attributed to differential habit strength as inferred from the number of prior reinforcements, examination of the data for individual subjects provides evidence of a strong inverse relationship between the effectiveness of the tone as an inhibitor and the level of conditioning. The distribution of total number of conditioned responses produced in acquisition was dichotomized at the median; a 2x2 frequency table relating this index of response strength to whether or not a conditioned response was made on any of the external inhibitor trials is presented in Table 2. The degree of association exhibited by this table

Table 1

Cochran Q Tests of Effect of Tone on Conditioning

	After 15 reinforcements	After 30 reinforcements	After 60 reinforcements
Group I			Q = 14.445* .001<p<.02
Group II		Q = 15.000 .01<p<.01	Q = 16.200 .001<p<.01
Group III	Q = 9.900 .01<p<.02	Q = 12.382 .001<p<.01	Q = 8.581 .01<p<.05
Pooled		Groups II and III Q = 22.963 p<.001	All Groups Q = 11.473 .01<p<.01

* df = 3 in all cases.

Table 2

Relationship Between Total Conditioned Responses and Effect of the Inhibitor

	Did not respond in presence of tone	Did respond in presence of tone
Below median number of total CRs	26	4
Above median number of total CRs	11	11

was evaluated by means of Fisher's exact test which yielded a probability value of .0351. Thus, support is provided for the Pavlovian contention that the effect of an extra stimulus presented during the interval of delay will be a function of the strength of the conditioned response being measured, specifically that a strong CR is harder to disrupt in this way than a weak one.

Figure 1 is a series of tracings showing the variety of effects produced by the introduction of the tone at the midpoint of the interval of delay. Although total inhibition of the CR occurred in 83.3% of the trials in which the tone was presented, it is of interest to examine some of the characteristics of the responses made on the remaining 16.7%. It might be, for example, that, even if the tone were not completely effective as an inhibitor, partial effectiveness would serve to lengthen the latency of the conditioned response as shown in the top panel of Figure 2. One might also suppose that in a few cases the tone would operate as a disinhibitor, removing the inhibition of delay thereby decreasing the latency of the conditioned response. Such an effect is shown in the bottom panel of Figure 2.

In order to see if either or both of these effects occurred with any regularity in those cases where the tone failed to block completely the production of a conditioned response, response latencies were recorded for each subject on the last trial on which the external inhibitor produced a CR. These, together with the latencies of the two immediately prior and two immediately subsequent conditioned responses, are presented in Table 3.

It can be seen from Table 3 that introduction of the tone has no particular effect on the mean latency of either the responses made to the tone or those made immediately after its presentation. There is, however, a significant increase in variability of these latencies; F-ratios were
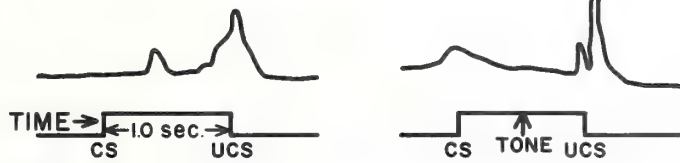
Figure 2. Tracings of actual records showing the effects of the tone on various eyelid reflexes.

EFFECTS OF AN EXTERNAL INHIBITOR
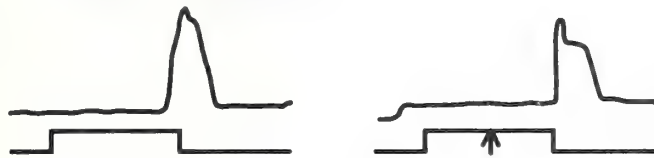## ON VARIOUS EYELID REFLEXES:

TRIAL n   TRIAL n+l

Table 3

Latencies in Seconds of Conditioned Responses
Prior to Tone, In the Presence of Tone,
and Following Tone

S#	2nd CR prior to tone	1st CR prior to tone	CR during tone	1st CR after tone	2nd CR after tone
24	.92	.92	.83	.63	.66
33	.79	.86	.92	.92	.69
41	.79	.76	1.02	.86	.73
43	.96	1.02	.63	.36	1.02
48	.92	1.06	1.00	.59	.69
20	.89	.89	1.02	1.00	.63
35	.73	.73	.66	.63	1.00
39	.76	.83	.69	.73	.96
40	.76	.83	.83	.66	1.06
44	.79	.79	.83	.76	.79
50	.89	.89	.59	.76	.79
53	.86	.96	.79	.79	1.02
19	1.02	.83	1.06	.89	1.06
32	.86	1.02	.89	.66	.59
42	.86	.63	1.06	.89	.63
Mean	.85	.87	.85	.78	.82
σ^2	.006	.013	.023	.014	.029

formed between the variance of the latencies obtained on the trials with the
external inhibitor and the pooled variance of the latencies of the two pre-
vious conditioned responses ($F = 2.467$, $df = 29/14$, $p < .025$) and between the
pooled variance of the two subsequent conditioned responses and the pooled
variance of the two previous conditioned responses ($F = 2.253$, $df = 29/29$,
$p < .05$). The comparison involving the latencies of the CRs obtained in the
presence of the external inhibitor and those of the two subsequent conditioned
responses failed to reach significance ($F < 1.00$). Thus we have evidence that,
in these subjects at least, if the external inhibitor fails to produce total
inhibition of the CR, it may alter the latency not only of the conditioned
response produced in its immediate presence, but of subsequent conditioned
responses as well.

Extinction Data. Table 4 presents the number of conditioned responses made by each of the three groups on the eight extinction trials. It will

Table 4

Performance in Extinction by Trials for the Three Groups

CS alone (n = 60)			CS plus tone (n = 57)				
Extinction trial 1	2	3	4	5	6	7	8
Group I 12	8	3	5	3	2	2	6
Group II 16	6	7	4	5	5	5	5
Group III 13	2	5	4	3	5	6	8

be recalled that the data in the last 5 columns are based on 57 subjects since the first subject run in each group was administered 10 straight extinction trials. For the 57 subjects who received three unreinforced presentations of the CS followed by five unreinforced presentations of the CS plus the tone, performance in the last straight extinction trial is, for comparative purposes, presented with performance on the 5 CS plus tone trials in Figure 9. A groups x trials analysis of variance of performance on these final five trials appears in Table 5.

One notes in examining Table 5 that a nearly significant difference in performance occurred as a function of the number of times the tone had been presented and reinforced during acquisition; the mean number of CRs per subject in Groups I, II, and III was .95, 1.20, and 1.47, respectively. This trend suggests that attempting to avoid the formation of discrimination during acquisition by reinforcing all presentations of the tone may have led to somewhat different levels of conditioning to the tone for the three groups. Indirect evidence that a discrimination might indeed have been

Figure 3. Number of conditioned responses presented trial by
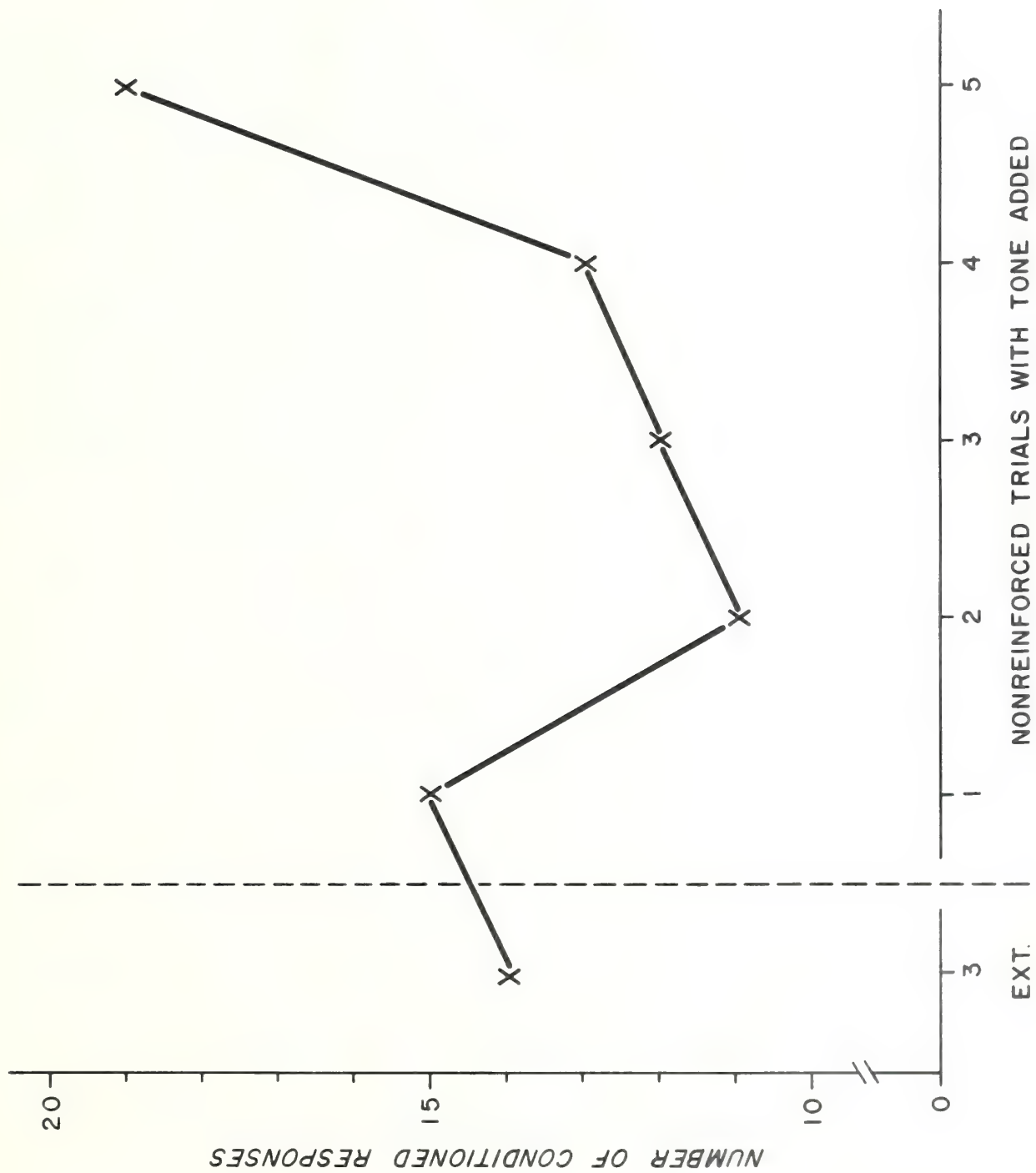trial for the last six extinction trials.

Table 5

Analysis of Variance of Conditioned Responses
Made to Tone in Extinction

Source of Variation	df	Sums of Squares	Mean Squares	F
Groups	2	10.133	5.067	2.924*
Trials	4	13.333	3.333	1.923
Linear	(1)	3.333	3.33	1.923
Quadratic	(1)	9.524	9.524	5.296†
Groups x Trials	8	13.867	1.733	
Total	14	37.333		

* p .10
† .025<p<.05

formed had the tone not been reinforced though it was presented at most only three times.

The most interesting feature of Table 5, however, is evidence for the reliability of the quadratic relationship depicted in Figure 1. The upward extension of the curve over the last trials tacitly appears to confirm Senger's finding that an external inhibitor in acquisition will, if presented during extinction, assume disinhibitory capacities. It must be noted, however, that these results are only suggestive because of the absence of necessary controls against which to assess the effect of further ordinary extinction trials and the extent to which there are CRs to the tone alone.

DISCUSSION

The principal result of this study was its confirmation in human eyeblink conditioning of the existence of a phenomenon of basic importance in classical conditioning: external inhibition. Specifically, it has been shown that the introduction of an extra stimulus during that portion of the interval of delay which is commonly thought to be excitatory will inhibit the production of a conditioned response.

The Pavlovian explanation for external inhibition is that a novel stimulus evokes an orienting reaction and that this reaction obliterates the conditioned response. The data support such an interpretation indirectly. It will be recalled that 39.4% of the responses made in the presence of the tone during acquisition were not considered in the analysis because they did not blend with the UCR whereas only 19.6% of the responses made in the absence of the tone were similarly eliminated. Inspection of the records indicates that the vast majority of the former were probably orienting responses; they occurred with appropriate latency and were usually of brief duration. In considering cases in which the tone failed to elicit an ori-

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enting blink but did inhibit the production of a conditioned response, it
should be recognized that the blink reflex is probably only a part of the
orienting reflex and perhaps not the essential part for the occurrence of
external inhibition. Therefore, failure of the reflex blink to occur to
all presentations of the tone cannot be taken as evidence that the orient-
ing reaction also failed to occur.

The present demonstration of the susceptibility of the conditioned
human eyeblink to external inhibition and, tentatively, disinhibition, af-
fords us the opportunity to verify at the human level the Pavlovian implica-
tions of these phenomena. An obvious next step, for example, would involve
manipulating the intensity of the external inhibitor to see if the amount of
external inhibition produced does vary directly with the intensity of the
extra stimulus; the results of our preliminary study compared with those of
the main study predict such an outcome since less inhibition was observed in
the presence of a visual stimulus than in the presence of a more novel audi-
tory one.

The Pavlovian investigators often used variations in the amount of
external inhibition produced by a standard extra stimulus to make inferences
about the amount of excitation present at the time of application of the ex-
ternal inhibitor. We should now be able similarly to investigate the hy-
pothesized growth of excitation during the interval of delay by presenting
tones at various points in such an interval and noting the amount of inhibi-
tion produced. This procedure might also shed light on the role of the ori-
enting reflex to the onset of the extra stimulus in the production of ex-
ternal inhibition; if external inhibition is nothing more than a result of
the orienting reflex and its refractory period, extra stimuli presented early
in the delay interval should have less of an inhibitory effect than those

presented later. The possibility exists, moreover, that an extra stimulus presented at a point in the interval too late to effect the anticipatory CR would have an inhibitory effect on the ICR. The present study yielded no evidence that a tone presented half-way through the interval generally had any such effect on the ICR, but the effect was observed in isolated instances (see Figure 3, third panel).

The results of the present study failed to confirm the expected presence of an induction effect in trials immediately following the presentation of the external inhibitor (see Figure 1).[1] Since the preliminary study which suggested the likelihood of an inductive effect differed from the present one in that the external inhibitor was a) visual and b) presented instead of the CS rather than in conjunction with it, it seems likely that one or both of these differences is responsible for the disparity of results. We would assume, with Pavlov, that induction varies with the amount of inhibition produced, yet the observation that external inhibition varied inversely with the number of prior reinforcements in the preliminary study would suggest that that procedure generated less inhibition than the present one. A resolution of this paradox must await further research, including replication of the preliminary study with proper controls such as were incorporated in the present design. It may turn out that reinforcement delivered in the presence of a totally novel stimulus temporarily sensitizes the subject so that in the preliminary experiment, we observed a pseudo-induction

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1. A t-test comparing the performance of Group II on trial blocks 10 and 11 (separated by their first experience with the tone) yielded a ratio less than unity. Since this difference is one of the largest to be found in Figure 1, either within or between groups or comparable or adjacent trial blocks, no effort was made to procure statistical support for either an induction effect or a locally perseverative inhibitory effect among the other points.

effect that was not, in fact, preceded by a great amount of internal inhibition. By contrast, in the present experiment, the external inhibitor apparently was not of sufficient intensity to produce an inductive effect, but since it was presented in the presence of the CS, subsequent reinforcement was probably not as sensitizing. Thus, it would appear that the demonstration of an induction effect following the presentation of an external inhibitor during the interval of delay must await the use of a more intense inhibiting stimulus.

Finally, it is advisable to reiterate and enlarge upon the cautions mentioned earlier attendant to interpretation of the extinction results. Although there is in these results the strong suggestion that the same novel stimulus which serves as an external inhibitor during acquisition acts as a disinhibitor after a certain amount of extinction has been permitted to occur, it is possible that what is being considered as evidence for disinhibition may only be the recovery of the orienting reflex. This would be interesting if it were true for it would imply that the extinction process not only involves the development of inhibition of conditioned responses, but of other types of responses as well. To check this possibility, it would have been necessary to introduce trials involving only the tone immediately after acquisition and compare the incidence of short latency blinks in that situation with that in the present procedure where the tone was introduced in the company of the CS after three extinction trials.

Just as in the case of external inhibition in acquisition, we do not know the role played in disinhibition of extinctive inhibition by the variables of stimulus intensity and the point in the delay interval at which the extra stimulus is presented. Moreover, in the research reported here, the number of extinction trials prior to the presentation of the disinhibitor

was held constant at three. If the number of such trials were manipulated, we might expect the amount of disinhibition to vary directly with the intensity of the disinhibitor but inversely with the number of prior extinction trials. It is difficult to suggest the manner in which varying the point in the delay interval at which the disinhibitor is presented would interact with these two variables. Presumably, extinctive inhibition should develop most readily where inhibition is already assumed to be present, early in the delay interval. Weak external stimuli should therefore be successful as disinhibitors later in the interval where some residual excitation may yet exist after a series of extinction trials.

APPENDIX

Appendix A

Instructions

In this study, we are interested in the blinking reaction of your eye to various types of stimulation. Therefore, in order to record your blinking, it will be necessary for me to put this headpiece on you and tape a little false eyelash to your eyelid. (Pause while the experimenter placed the headband and attached the eyelash.)

At various times during the experiment, a light will appear in that little window. Also from time to time, a puff of air will hit the corner of your right eye. Now all you have to do is relax and let your eye's reactions take care of themselves. In other words, try to forget about your blinking altogether. Stay alert, though, and concentrate on the stimuli as they are presented.

During the experiment, it will be helpful if you keep your gaze on the little window. There will be times when the light will not be on very long and you might miss it if you are not looking at it.

Finally, remember that we are interested in your natural reactions to the stimuli, so please don't close your eyes voluntarily at any time during the presentation of a stimulus; just relax and let nature take its course.

If anything unusual should happen during the experiment such as the eyelash coming off or the headpiece slipping down over your eyes, you can

call me simply by talking; that Intercom is on and I will be able to hear you.

Appendix B

This appendix presents the acquisition data for each subject in terms of number of CRs per block of three trials. The ordinary acquisition trial blocks are numbered 1, 2, ... 22. The single trials on which the tone was presented are labeled ordinally I_1, I_2, or I_3 and are inserted at the appropriate point in the acquisition series; a CR on such a trial is designated by a +.

The data for Group I are presented in Table 6, those for Group II in Table 7, those for Group III in Table 8.

Table 6

Number of Responses in Acquisition for Group I in Blocks of Three Trials

Blocks of Three Trials

Subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	T_1	21	22

Table 7

Number of Responses in Acquisition for Group II in Blocks of Three Trials

Blocks of Three Trials

Table 8

Number of Responses in Acquisition for Group III in Blocks of Three Trials

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